Solar Home Systems in Ho Chi Minh City: A promising technology whose time has not yet come

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14 December 2015

SOLAR HOME SYSTEMS IN HO CHI MINH CITY:

A promising technology whose time has not yet come

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December 2015

Abstract

This study examines the constraints to the uptake of Solar Home Systems (SHS) in Ho Chi Minh City (HCMC), Vietnam. SHS are photovoltaic systems which generate electricity for residential properties. The limited numbers of SHS installed in HCMC are mostly on-grid systems with backup batteries to supply electricity during evenings and/or power cuts. Semi-structured interviews with SHS installers, manufacturers and users, plus government agencies and technical experts identify policy constraints and the cost of systems as major constraints. Cost-benefit analysis is then used to estimate the payback period for three representative SHS. Raising residential electricity prices and introducing net metering or a feed-in tariff could dramatically shorten the payback periods for SHS. In the next five years, these and other expected changes to the electricity market will make SHS more finally attractive than at present. SHS also have the potential to generate supplement electricity during peak times, thereby diversifying and greening the energy mix. SHS therefore represent a promising technology for HCMC in the future.

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Abbreviations

ECC	Energy Conservation Centre
EVN	Electricity Viet Nam
FiT	Feed-in-tariff
GHI	Global Horizontal Irradiation (or Irradiance)
GW	Gigawatt
HCMC	Ho Chi Minh City
kWh	kilowatt hour
kWp	kilowatt peak
MW	megawatt
MWh	megawatt hour
MOIT	Ministry of Industry and Trade
PV	Photovoltaic
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SHS	Solar Home Systems
RMIT	Royal Melbourne Institute of Technology
Wp	Watt peak
VND	Viet Nam Dong

Acknowledgments

The research team would like to express their sincere appreciation to Pham Nam Phong of Vu Phong Solar (SolarV) and to Koos Neefjes (formerly UNDP and UNEP) for many useful discussions during the course of this project. They thank Ondris Puis of RMIT's Centre for Communication and Design for the excellent art-work in Figure 8. We also thank members of the *Tinh Te* online solar energy forum for their enthusiasm and inputs.

1. Introduction

This report contains the detailed results of a RMIT Vietnam Internal Research Grant study on 'Constraints to the Uptake of Solar Home System in Ho Chi Minh City'. Solar Home Systems (SHS) typically consist of one or more photovoltaic (PV) panels, an inverter, control panel, metering, mounting and wiring which can generate electricity for residential users.[1] Most SHS in Ho Chi Minh City (HCMC), which is Vietnam's commercial capital and largest city, also include back-up batteries to supply electricity during power cuts and/or during the night. At present, there are relatively few SHS installed in the urban wards of HCMC, largely because of their high initial cost, long payback periods, policy and other constraints. However, with a number of expected changes to both domestic policy and external costs, we believe that in the future SHS have a role to play in both diversifying Vietnam's evolving energy mix and in contributing to its Green Growth Strategy.

The three main research questions that have been investigated by this project are:[2]

1. What are the main economic, technical and policy constraints to the uptake of SHS in HCMC?
2. How do these constraints vary by district, type of system and socio-economic status?
3. What can be done, by industry, policy makers and researchers, to improve the uptake and use of SHS in urban Vietnam?

To answer these questions, the research team believed that a mixture of quantitative and qualitative methods (i.e., mixed methods) was needed. We have therefore conducted a review of the current status of the electricity market (see Section 2) and the potential of solar power (Section 3) with special reference to HCMC. Based on approximately 30 semi-structured interviews with SHS distributors, manufacturers, installers and users plus selected government agencies and technical experts located in and around HCMC, we classify and describe the main types of SHS that are currently available in HCMC (Section 4).

[1] Solar water heating systems, which are popular in some districts of HCMC, are not considered in this report as they use PV panels to heat water rather than to generate electricity.
[2] Due to the limited number of SHS installed in HCMC and difficulties in contacting SHS users, it is only possible to answer research question 2 partially.

The semi-structured interviews also help us to identify the perceived constraints to the adoption and uptake of SHS in HCMC, and how these constraints vary across our different research participants (Section 5). Cost-benefit analysis was then carried-out to estimate the likely payback period for three representative SHS: a medium-sized 1 kilowatt peak (kWp) grid-tied system with battery backup, a larger 4 kWp grid-tied system with backup, and a smaller off-grid 65 Watt peak kit system (Section 6). Finally, we draw out some conclusions and wider policy implications of our research, concluding that SHS in both HCMC, and Vietnam more generally, are a promising technology whose time has not yet come.

2. Current Status of the Electricity Market in Vietnam

Over the last 15 years, electricity consumption and production in Vietnam has grown by 12 to 16 per cent per annum with production of electricity approximately doubling every six years (Figure 1). During this period, per capita electricity consumption has grown from less than 50 kW per capita to more than 1200 kW per capita in 2013, with industry and the household sector being the biggest consumers (Asian Development Bank, 2015). In 2014, industry and households accounted for 55 per cent and 36 per cent of total electricity consumption, with agriculture and services consuming the remainder (Solidance, 2015). The strong growth in electricity consumption is attributable to Vietnam's fast economic growth, rapid increases in the standard of living, urbanisation and the electrification rate. As of 2012, with the electrification rate of 99 per cent according to World Development Indicators, Vietnam had the highest electrification rate of all developing countries worldwide.

Based on forecasts from the Master Plan of National Electricity Development (Power Development Plan VII), the demand for electricity in Vietnam will continue to grow at 11.15 per cent annually from 2016 to 2020 and then at 7.4 to 8.4 per cent per annum in the following decade (2021-2030). Due to the strong increase in industrial and residential demand for electricity, electric power shortages are expected in a foreseeable future.

As shown in Figure 1, Vietnam has experienced a strong growth in electricity production (with an average annual growth rate of 15.1 per cent from 1995 to 2008, which is twice the average annual GDP growth rates of 7.5 per cent). However, Vietnam still has to import 5 to

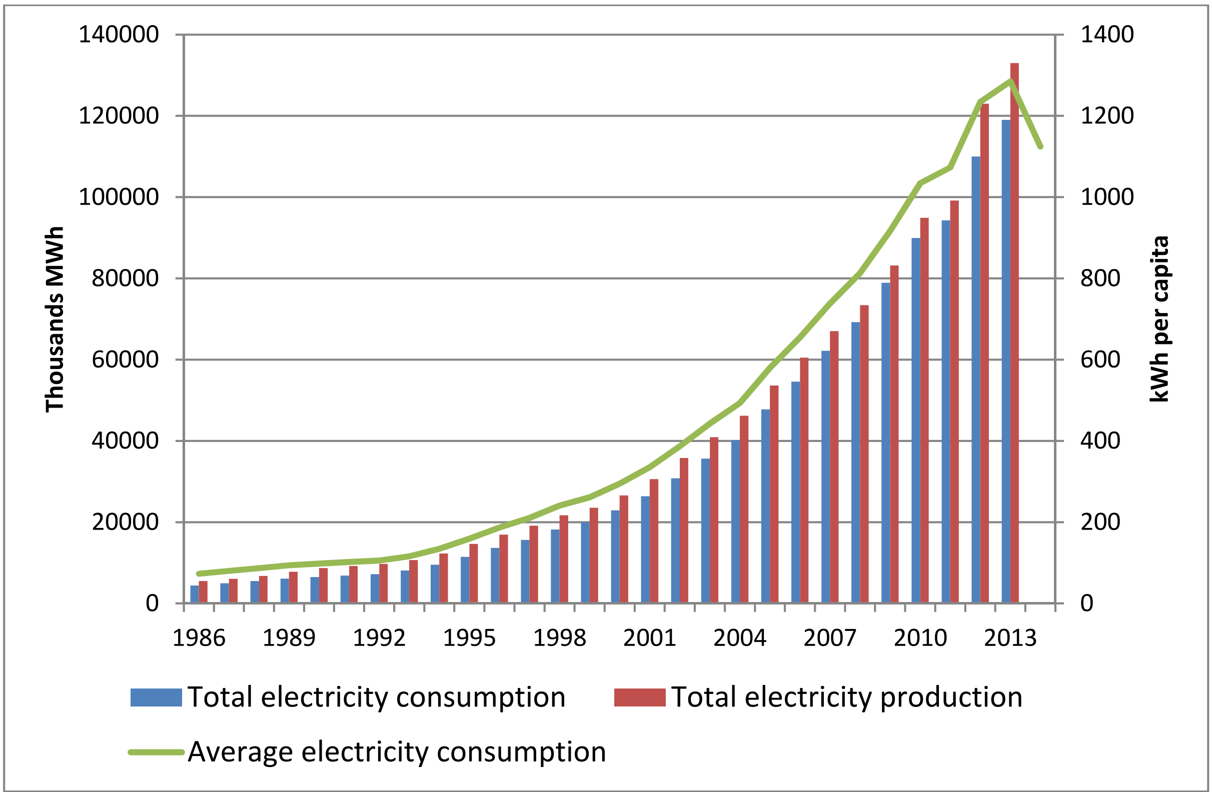
6 per cent the electricity supply annually. The state-owned Electricity of Vietnam Corporation (EVN) is currently the monopoly distributor of grid (mains) electricity in Vietnam, and has five power companies which provide 70 per cent of the total electricity production in the nation. Meanwhile, foreign direct investment (FDI) and private sector provide only a minimal percentage of the electricity needed for the economy.

In recent years, irregular and unstable electricity supply has been a stumbling block to the economic development of Vietnam, in particular her rapidly growing manufacturing sector. Power cuts (both scheduled and due to unplanned grid outages) are frequent in both rural and urban areas. The System Average Interruption Frequency Index (SAIFI), which measures the average number of power cuts experienced per customer during a year, was 40.16 nationally in 2012. The System Average Interruption Duration Index (SAIDI), which shows the average annual duration of power interruptions per electricity customer, was 7,643 minutes in 2012 and is reported to have fallen to 3,134 minutes in 2014 (Lietl, 2014; EVN, 2014). In 2012, HCMC had much lower SAIDIs and SAIFIs (of 21.13 interruptions and 2,768 minutes) than nationally, although the frequency of power cuts was higher than in Hanoi (Leitl, 2014). EVN in HCMC targets a reduction in the SAIDI to 1,782 minutes by the end of 2015 (ADB, 2014).

Vietnam's unstable power supply is attributable the use of out-dated production and transmission technology and is accentuated by inefficiencies in its usage patterns. Compared to neighbouring countries, Vietnam has seen little improvement in the overall efficiency of its power system. For example, between 2008 and 2012, Indonesia and Thailand successfully reduced their electricity distribution losses from 11.8 to 10.7 per cent and 7 to 6 per cent, respectively, while Vietnam's distribution losses have remained roughly constant (Solidiance, 2015).

Several important specific targets are listed in the National Power Development Master Plan VII for the power sector in the period from 2010 to 2020, with view to 2030. First, increase electricity production and import to a total of 194-210 billion kWh by 2015, 330-362 billion kWh by 2020, and 695-834 billion kWh by 2030. Second, generating electricity from renewable resources should be given priority by increasing the renewable electricity yield from 3.5 per cent of total electricity generation in 2010 to 4.5 per cent in 2020 and 6 per cent in 2030. Third, the rural and mountainous electrification program should be speeded up in order to ensure that almost all rural households will have electricity by 2020.

Figure 1: Vietnam's Total Electric Consumption and Production, 1986-2014



Source: World Development Indicators 2014

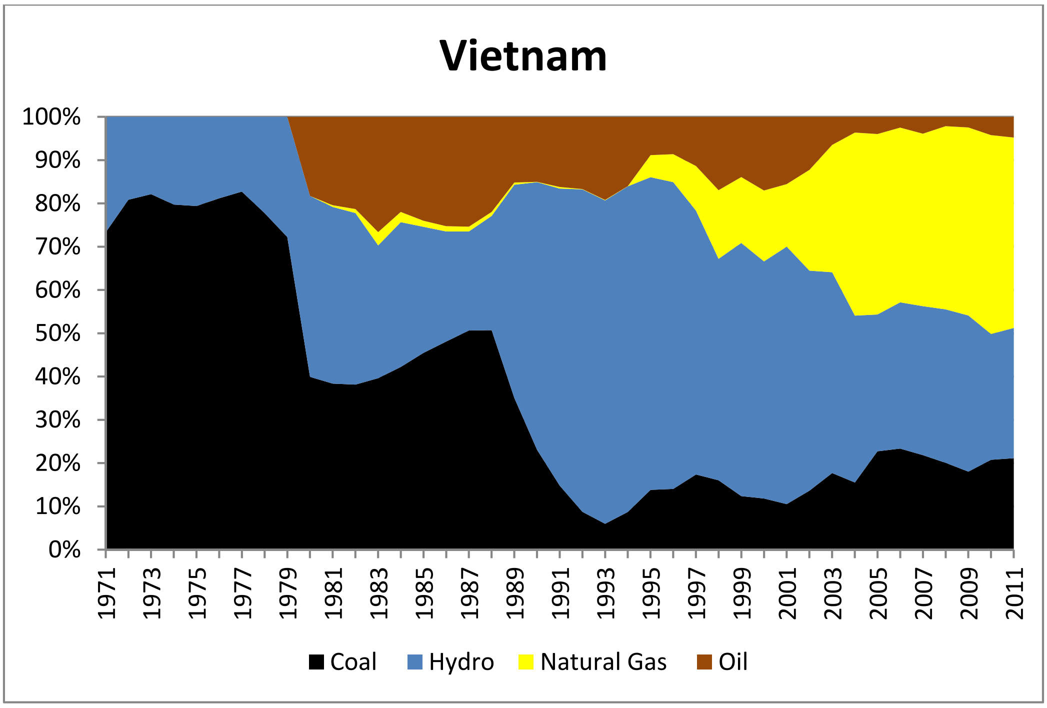
Figures 2(a), (b), (c) and (d) illustrate the sources of electricity production in Vietnam and some neighbouring countries including Thailand, Indonesia and Philippines. These countries are chosen for this comparison, as we believe that the electricity industry in these countries might suggest where Vietnam may be in 10 to 15 years. Since the late 1990s, all the countries have diversified their sources of electricity production while reducing their reliance on oil as a source of power. Specifically, since the 1990s, Vietnam has relied on natural gas, coal and hydroelectric sources for producing 80 to 90 per cent of its electricity, while roughly 60 to 90 per cent of Thailand's electricity comes from natural gas and coal.[3] In Indonesia, about 70 to 80 per cent of electricity is generated from natural gas, coal and hydro whereas in the Philippines, oil has declined dramatically as a source of significant

[3] Hydroelectricity only contribute a small percentage of electricity production in Thailand

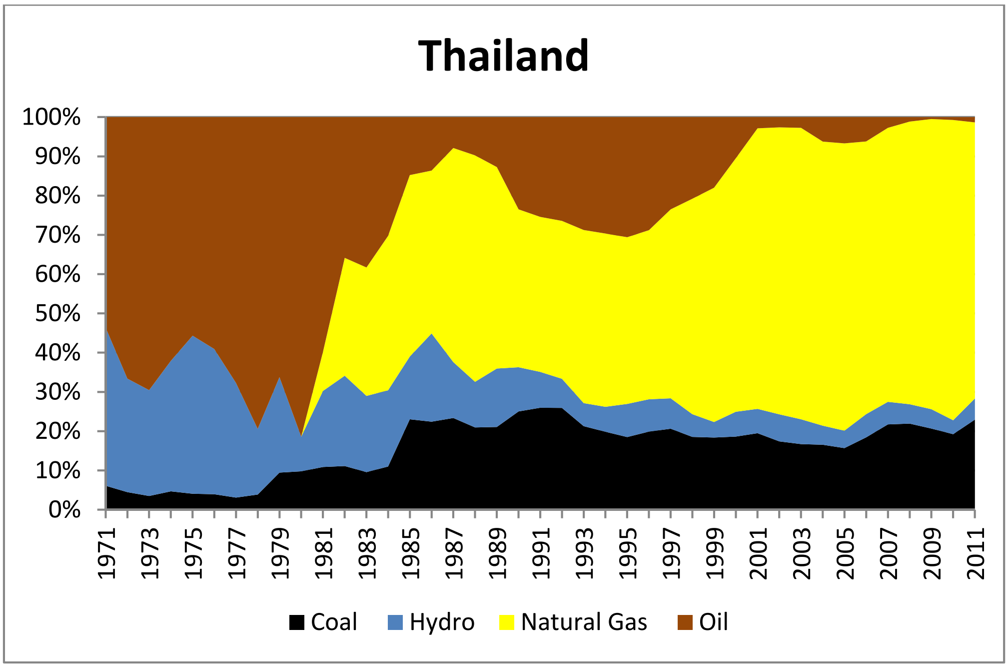
electricity since the 1990s, and approximately 90 per cent of the country's electricity now comes from natural gas, coal and hydro.

Figure 2: Sources of Electricity Production in Vietnam and some Neighbouring Countries

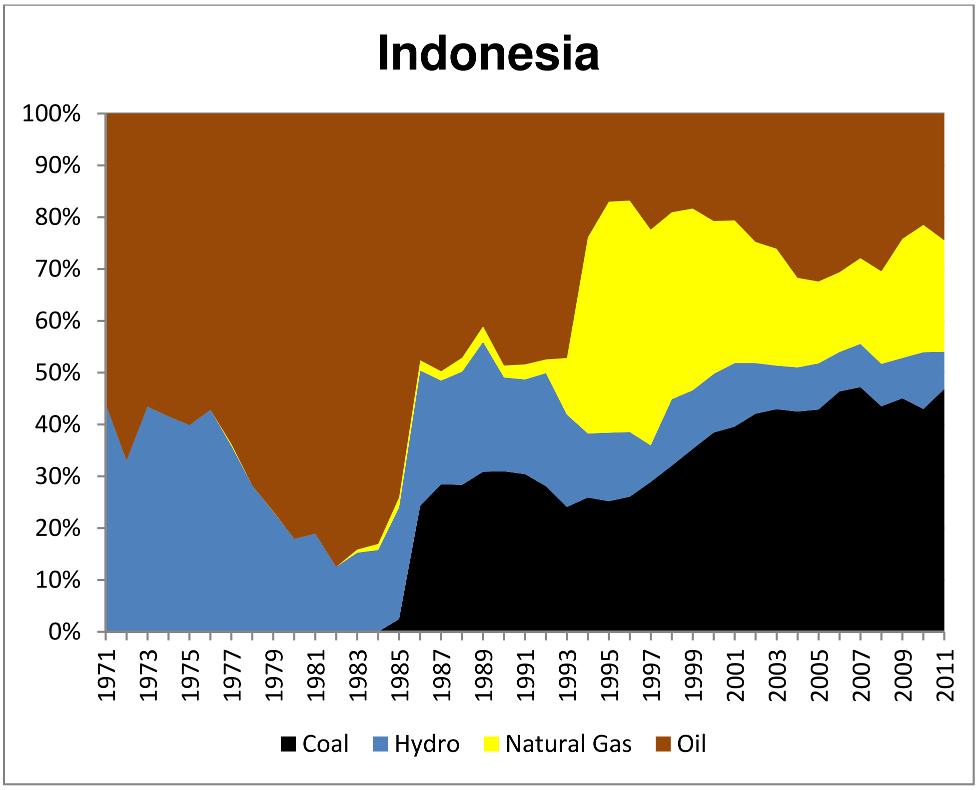
(a)



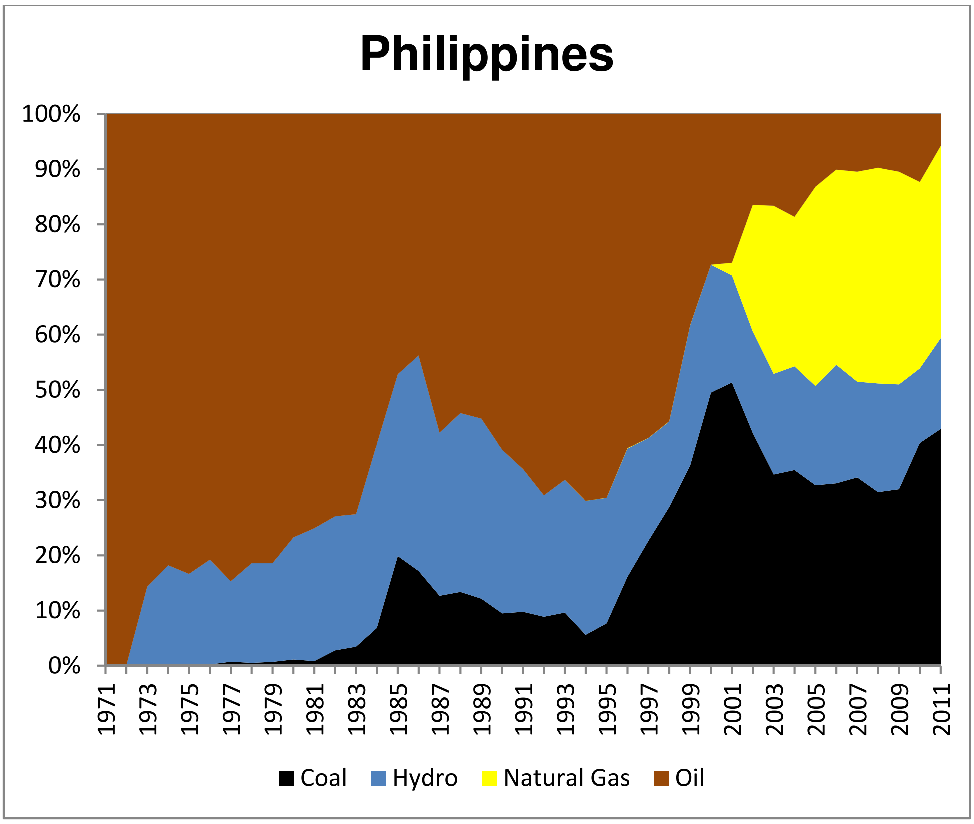
(b)



(c)



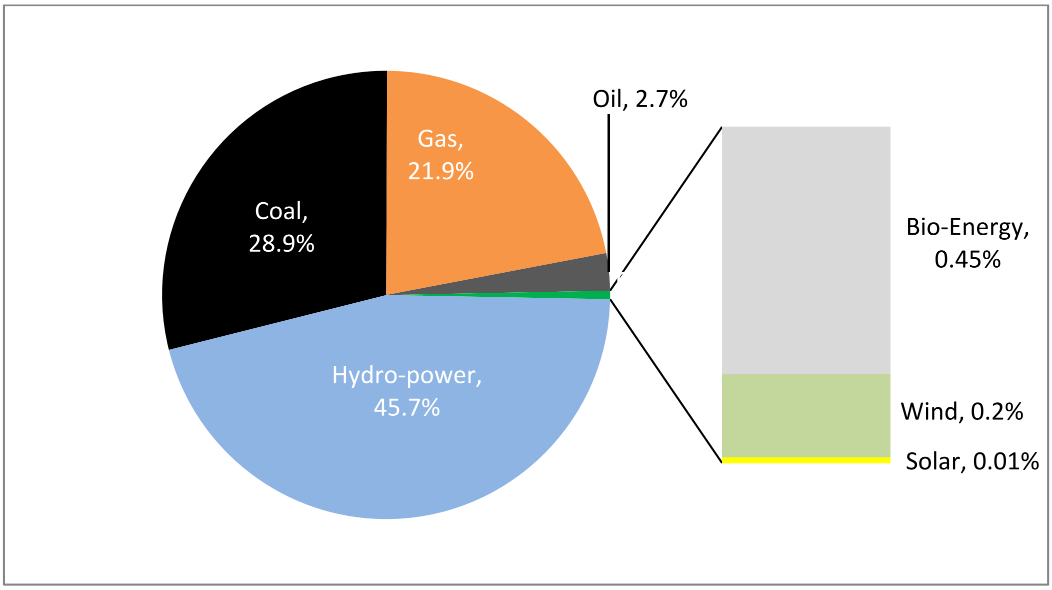
(d)



Source: World Development Indicators 2014

As of 2014, hydropower is the main source of the electric power production in Vietnam with a share of 40 per cent in electricity generation, followed by coal with 29 per cent and natural gas with 22 per cent (Figure 3). Hydroelectric power generation is heavily dependent on the season while domestic coal and gas resources and limited (and will increase Vietnam's fossil import dependency in the future). With the exception of hydropower, the generation on of renewable energies in Vietnam, such as wind and solar power, are in very early stages of development.[4] Imports from neighbouring countries, in particular Lao PDR, account for a small (1.6 per cent in 2014) but a growing share of national electricity usage.

Figure 3: Installed Capacity by Generation Technology, 2014



Source: National Power Development Master Plan VII.

Under the National Power Development Master Plan VII, Vietnam's total generating capacity is expected to grow to 146,800 MW, of which hydropower would account for 11.8 per cent, energy storage hydropower 3.9 per cent; coal thermal power 51.6 per cent; and gas 11.8 per cent (of which LNG 4.1 per cent); renewable energy 9.4 per cent; nuclear power 6.6 per cent; with imports making up the remaining 4.9 per cent. Electricity output in 2030 is projected to be 695 billion kWh.

[4] Hydropower is not generally classified as renewable energy. However, small hydropower plants (with less than 30 MW installed capacity) are often considered to be "renewable" or "green" energy in Vietnam, as they are run-of-river schemes which can be installed with negligible environmental impact and using existing infrastructure. Small scale hydro plants accounted for 4.6 percent of installed capacity in 2014.

Vietnam’s retail electricity prices vary between weekday, time of the day, regions, sectors, voltage levels and consumption levels. Average tariffs by sector are shown in Table 1.

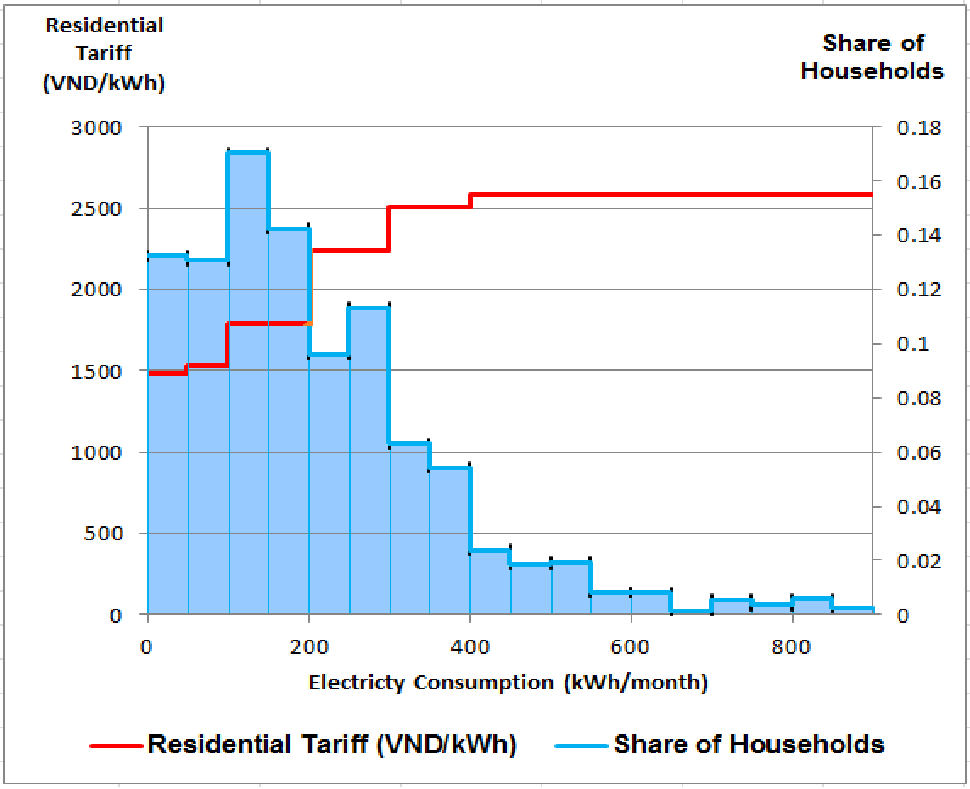
Table 1: Retail Electricity Prices by sector, 2015

Sector	**Electricity price** (VND/kWh)	**Electricity price** (US cent/kWh)
Administration	1,573.5	7.3
Business	2,466.11	11.4
Manufacturing	1,653.25	7.6
Residential	2,039.43	9.4
Average	1,933.07	8.9

Source: Ministry of Industry and Trade Decision No. 2256/QĐ-BCT 2015. The exchange rate used is US$1=VND 21,673 as of 14 July 2015.

The Vietnamese Government sets retail electricity tariffs for the whole country. Unlike business and commercial tariffs, which vary according to the hours of usage, residential electricity tariffs are tiered starting at only VND 1,484 (6.8 US cents)/kWh for consumption of less than 50 kW per month and rising in steps to VND 2,587 (11.9 US cents)/kWh for consumption of more than 401 kWh per month (Figure 4). Currently Vietnam’s five electricity power distribution companies all follow the same pricing schedules, so all customers pay the same price for using same amount of electricity. This is expected to change in the future with the further deregulation of the electricity market.

Figure 4: Residential Electricity Consumption and Tariffs in HCMC

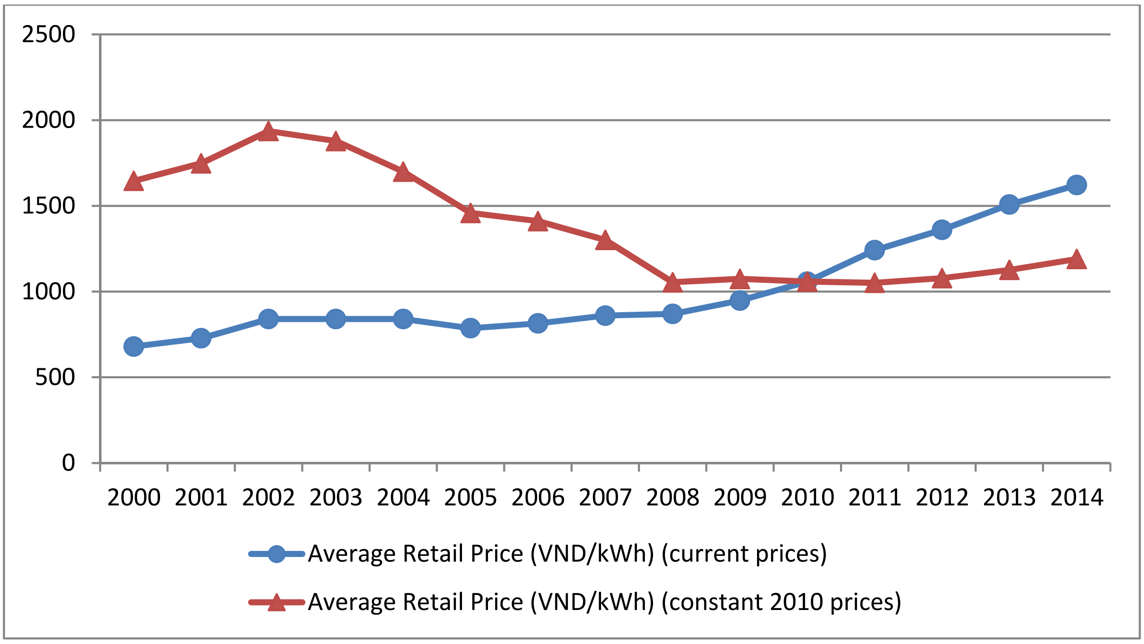


Sources: Residential electricity tariff in Vietnam http://www.evn.com.vn/EVN-khach-hang/EVN-khach-hang/Gia-dien/Bieu-gia-ban-dien/Bieu-gia-ban-le-dien/Index.aspx . Residential electricity consumption is based on authors' calculations from Vietnam Household Living Standards Survey, 2012

Figure 4 also shows the distribution of residential electricity consumption in HCMC in 2012. Each bar in this histogram represents incremental consumption of 50 kWh per month, so the first two bars of this graph would be charged at residential pricing tiers 1 and 2, the next two bars at residential pricing tier 3 and so on. It can be seen from the distribution that there is a high demand group whose household electricity consumption is more than 250 kWh per month. This high demand group accounts for about half (43%) of the population of HCMC. For this group, modal household consumption is between 250 to 300 kWh per month, which corresponds to residential pricing tier 4. However, with recorded growth in consumption, it may have increased to residential tier 5 for some households. Since we expect that the majority of households considering the installation of a SHS will be relatively well-off households, the opportunity cost of the electricity generated would fall into the residential pricing tiers 4 or 5.

Historic average retail electricity prices in Vietnam are shown in Figure 5. From 2005 to 2011, retail prices were adjusted once every year. Since then electricity prices have normally been adjusted twice a year, once during the summer and once towards the end of the year. From 2000 to 2014, nominal electricity prices in VND terms have steadily risen and increased by more than doubled. However, as the VND has been experiencing significant growth in the price level during this period, prices change are quite different in real terms. Specifically, in real terms, the average electricity tariff in Vietnam increased between 2000 and 2002, reached a peak at 2002 and then consistently decreased until 2008. From 2008 to 2011, the real price of electricity in Vietnam was relatively stable and during the past three years till now, the trend has been a gradual increase.

Figure 5: Average Retail Prices of Electricity in Vietnam, 2000-2015



Source: VP Bank Securities (2013) and authors' own calculations from the Ministry of Industry and Trade's regulations on electricity prices

Nevertheless, at present, the prices that most EVN's customers pay do not cover the actual costs of electricity generation. The retail electricity price in Vietnam is calculated based on generating costs (which comprise 75 to 80 per cent of retail prices), transmission costs (7 per cent), distribution costs (10 per cent) and overhead costs (3 to 8 per cent) (VP Bank

Securities, 2013). The current price of electricity is generally believed to be lower than cost of production, transmission, and distribution.

A recent UNDP study argues that subsidies are indirect, through preferential treatment of energy producers and distributors (UNDP, 2014). EVN and its subsidiaries, for example, receive low interest credit for investment, together with subsidised prices for inputs such as coal and gas. This results in substantial foregone revenue to EVN and has contributed to its increasing level of debt.[5] The structure of the electricity price schedule in Vietnam is also not equitable with cross-subsidies between different customer categories (Nguyen, 2012). Industrial and commercial customers who use electricity at higher voltages which cost less to supply must pay more than residential customers who use electricity at lower voltages, and whose distribution networks cost more and have higher distribution losses. In addition, the tiered residential pricing system is manipulated by the government to reduce electricity costs to the low-income (or at least low consuming) households.

Finally, it should be noted that the retail prices of electricity in Vietnam are among the lowest in Asia (Table 2). For instance in 2014, Cambodia's average electricity tariff was 2 to 2.7 times higher than Vietnam's, while the retail price in the Philippines was approximately double that in Vietnam. Only countries, such as China and Indonesia, which are known to subsidise their residential electricity prices have average retail electricity prices similar to Vietnam. Other countries, such as Brunei, Malaysia and South Korea, have tiered tariff structures which favour households with modest energy consumption level but then rise quite steeply.

[5] Between 2007 and 2012, EVN's debt grew from VND86 trillion to VND 246 trillion (Asian Development Bank, 2015).

Table 2: Retail Electricity Prices in Vietnam and Neighbouring Countries, 2014

Country	Electricity Price (US cents/kWh)
Brunei	1-15
Cambodia	13-19
China	8
Indonesia	9
Japan	20
Malaysia	7-19
Philippines	14
Singapore	21
South Korea	5-15
Thailand	6-13
Vietnam	**7.2**

Source: Websites of National Electricity Companies

The current status of renewable energy pricing in Vietnam is summarised in Table 3. At present FiT are only available for biogas and wind power, with a higher FiT for commercial wind plants than biomass. However, a pilot study of FiT for solar power was approved by the HCMC Provincial Government in March 2005 (Decision 242) and will be carried out by the EVN and the Energy Conservation Center (ECC) of HCMC over the next two years. Additional studies on geothermal power and biogas are also underway.

Table 2: Status of Renewable Energy Pricing, 2014

Renewable Energy Source	**Existing**	**Under development**	**Level**
Small Hydro	ACT		Issued annually
Wind	FiT	Higher FiT	Currently: 7.8 + 1 US cents/kWh
Biomass	FiT, Avoidable Cost Tariff		Cogeneration: 5.8 US cents/kWh Avoidable cost tariff of US cents 4.43/kWh
Municipal solid waste	FiT		Landfill gas combustion: 7.28 US cents/kWh Waste incineration: 10.05 US cents/kWh
Biogas		FiT	Studies completed, FiT drafted
Solar		FiT	Implementing studies
Geothermal		FiT	Implementing studies

Source: Based on "1st GDE/GIZ Summer Academy on Bio-Energy Applications in Viet Nam." 2014. GIZ.

As will be noted in Section 6, for the type of distributed energy generation involving SHS, net metering (in which a surplus electricity produced is valued at the same price as electricity purchased from the grid) is simpler to install and operate to than a FiT (in which renewable electricity generated typically receives a higher price than the electricity which households purchase from the grid). EVN and the provincial government of Danang have carried out trials of two-way electricity meters suitable for net metering.

3. Potential and Current Status of Solar Power in Vietnam and in Ho Chi Minh City

This section examines the potential and current status of solar energy first in Vietnam and then in HCMC, its most populous city and commercial centre.

Central and Southern Vietnam have great potential for developing solar energy generation. Below the 17th parallel, total solar radiation averages around 4 kWh/m2 per day and remains steady throughout most of the year (Trinh, 2009). When expressed on an annual basis, GHI in southern Vietnam is around 1,800 kWh/m^2/year, which is among the highest in South East Asia (Appendix 1A). Higher levels of GHI are however, recorded in eastern Java and Sulawesi in Indonesia and northern Luzon in the Philippines, along with much of South Asia. The solar resource map in Appendix 1B show that global horizontal irradiation (GHI) per day averages 3.4 kWh/m^2/day in the north of Vietnam, 3.8 kWh/m^2/day along the North Central Coast, and 4.8 kWh/m^2/day in the Central Highlands, South Central Coast and South (AECID-MOIT, 2014). In some coastal areas of the South Central Coast, GHI can be as high as 5 kWh/m^2/day. Based on these maps, the theoretical potential of solar power nationally is estimated to be 60 to 100 gigawatt hours (GWh) per year for large concentrated solar power systems and 0.8 to 1.2 GWh/year for flat plate PV plants (AECID-MOIT, 2014).

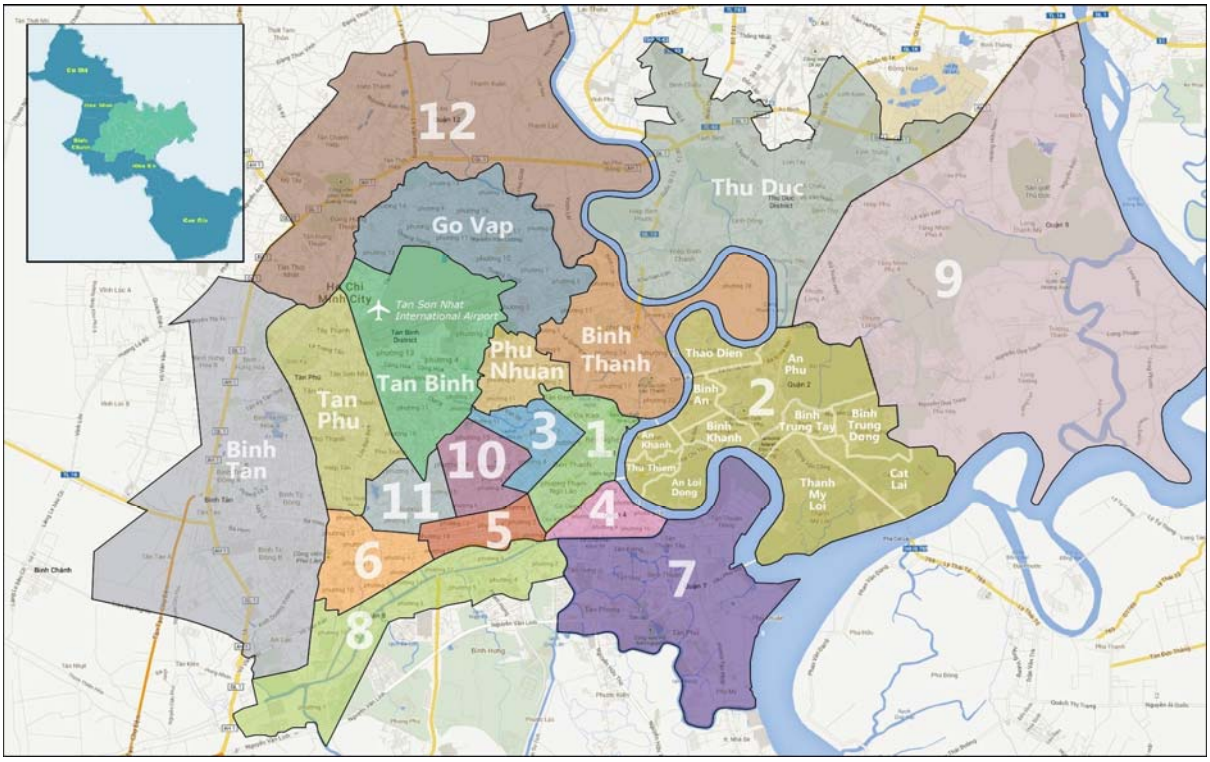
HCMC (formerly known and still popularly called 'Saigon') is Vietnam's largest city and commercial centre. With a GDP per capita of US$8600 (expressed in current PPP US$) in 2014, it is also Vietnam's richest province.[6] In the last decade and a half, the population of HCMC has grown extraordinarily fast. Official statistics show that the population of HCMC grew from 5.1 to 7.5 million between 1999 and 2011.[7] To this figure, between 500,000 and 1.5 million unregistered urban migrants should be added. HCMC is expected to reach 'megacity' status (a population over 10 million) within the next five years. Administratively, HCMC comprises 19 urban districts and 5 rural districts (Figure 7). The most well-known

[6] HCMC is both a municipal city and a province. It is both richer and larger (in terms of both area and population) than Hanoi, the national capital, which is located some 1,154 km to the north. Vietnam's GDP in 2014 was US$5,529 per capita.

[7] These figures are census and inter-decadal census for 'usual residents' of HCMC and exclude many unregistered migrants. Both urban wards and rural communes are included.

districts are District 1 (the central commercial district), the adjacent densely populated districts 3 to 5, the rapidly developing District 2 on the opposite bank of the Saigon river, and District 7 (the international business district, where RMIT Vietnam's main campus is located) to the south. Most of the limited solar generating capacity in HCMC is located in Districts 2, 7 and 9 plus the outlying Can Gio district (see insert to Figure 7).

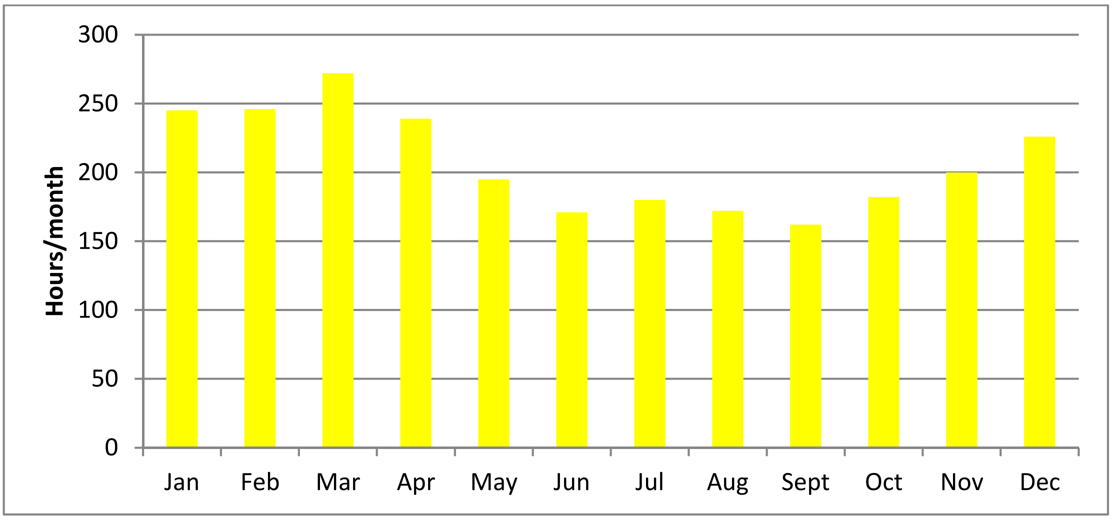
Figure 7: Administrative Map of Ho Chi Minh City



Source: wordpress.com
Note: the main map shows HCMC's central urban districts, the inset shows HCMC's provincial boundaries

Figure 7 shows the average number of sunshine hours recorded at the Tan Son Nhat Metrological Station in HCMC. Although the average number of sunshine hours per month drops during the rainy season in the middle of the year, sunshine hours always exceed 150 hours per month and are both higher as well as more even distributed than in Northern Vietnam, which has prolonged cloudy weather during the winter and early spring.

Figure 8: Average Sunshine Hours in Ho Chi Minh City



Source: Data from Tan Nhat Son Metrological Station

Despite solar power having great potential in central and Southern Vietnam, uptake of most solar technologies has been limited, especially at the household level. The ECC of HCMC estimates that in 2014 there was approximately 3.99 MW of renewable energy generating capacity in Vietnam, of which solar systems accounted for 365.5 kW.[8] Solar energy generating capacity in HCMC is estimated to be less than 200 kW.

The largest commercial solar power system in HCMC - also in the entirety of Vietnam - is installed at Intel's Saigon Hi-Tech Park facility in District 9 (*SaiGon Giai Phong Daily*, 2012). Comprising of 1,092 solar roof panels and 21 adapters, the system began operating in April 2012 and provides around 321,000kWh of electricity per year. This is equivalent to the amount of electricity consumed by approximately 500 households.

The largest concentration of solar panels for residential use in HCMC is located in Thieng Lieng hamlet, an island commune, in Can Gio district. The VND 14.8 billion project began operation in 2011 and installed 172 small (525 Wp) SHS in the commune; it was funded by the HCMC Electricity Company (*SaiGon Giai Phong Daily*, 2011).

[8] Note that these figures exclude solar water heating systems, as they do not generate electricity. Solar water heating systems are common in many parts of southern Vietnam, including HCMC, in part because of a VND 1 million installation subsidy. This subsidy was initially a pilot scheme for HCMC and was administered by ECC from 2008 to 2010; it now applies nationwide and is administered by EVN.

Another “large” commercial solar system is the 212 kWp project at the Big C supermarket/shopping centre in the neighbouring province of Binh Duong (*Saigon Times*, 2012). This project, worth more than VND 11 billion and installed by Schneider Electric Vietnam, began operating in early 2013. The system produces about 230,000 kWh of electricity, meeting 7 per cent of the total power demand of the centre.

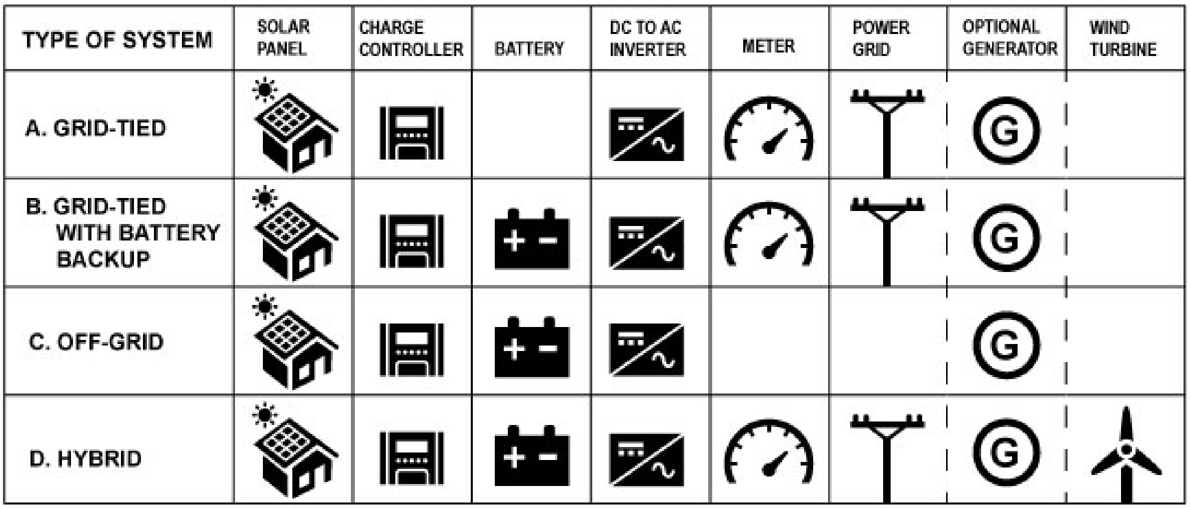
It should be noted that large systems as described above are far and few in between. To date, the number of installed solar systems—both residential and commercial—remains limited in both HCMC and Vietnam.

4. Different Types of Solar Home Systems

For the purpose of our research, SHS are defined as systems that generate electricity for residential use. We do not include solar water heaters, which generate heat instead of electricity, and which are now quite common in many parts of HCMC.

Four main types of residential solar electric power systems may be identified: grid-tied without battery backup, grid-tied with battery backup, off-grid, and hybrid systems. These systems vary in how closely connected they are to the electricity grid and in whether they have a power backup source. The main components of these four SHS are summarised in Figure 8 below:

Figure 8: Main Types of Solar Home Systems



Source: Artwork by Ondris Pui, Centre for Communication and Design, RMIT Vietnam

Grid-Tied Systems without Battery Backup

A grid-tied solar power system is connected to the home and to the electricity grid. The system allows its homeowner the flexibility to obtain power from either the residential solar system or the utility grid by mixing between the two sources. In most countries, homeowners can draw power from the grid during periods of excess demand and sell power to the grid during periods of excess production in a practice known as net metering. Depending on the utility, homeowners will get credit for their excess production.

The prime advantage of this type of systems is the ability to balance the system production and home power needs. Another advantage is the lower initial cost to install the system[9]; grid-tied systems are the second least costly type of SHS after solar kits. They are also easy to design and install. Their main disadvantage is that when the grid power goes out, households are also without power.

In HCMC, grid-tied systems without battery back-up are very rare despite their advantages in cost and installation. The primary reason is because households that use solar power

[9] A grid-tied system without battery backup consists mainly of only two parts: the solar modules and the inverter. The solar modules are installed on a roof or a pole; their purpose is to convert sunlight into DC power. The inverter then converts the DC power into AC power and feeds the AC power into the breaker panel and/or onto the electricity grid. This type of systems typically has no moving parts or batteries, which significantly reduces the initial cost.

require a constant and stable secondary source of electricity to supplement the cheaply priced yet unreliable power grid or to make up for the absence of the power grid altogether. This is a situation that grid-tied systems are not designed to resolve. Another crucial barrier is that excess electricity generated by these systems cannot feed be back into the electricity grid due to the non-existence of net-metering and FiT in Vietnam.

Grid-tied Systems with Battery Backup

Grid-tied solar power systems add batteries as a backup source of electricity to balance production and demand and to safeguard against power outages. This is accomplished by using the excess power to charge the batteries and store electricity when production exceeds demand. The batteries then make up for the power shortfall when the grid power goes out and during the night, when no solar electricity can be produced.

Grid-tied systems with batteries as back up offer more flexibility than grid-tied systems since they remain operational for some time when either or both the residential solar systems and the power grid become non-accessible. On the other hand, these systems are more costly and more complex to design and install. The installer must first determine how much power is required and for how long (i.e. how many hours) to adequately size the batteries. Occasionally, a small gas/diesel generator may be added to replenish the batteries during prolonged outages. Charging and discharging batteries also reduce the overall efficiency of these systems.

For these reasons, grid-tied systems with batteries are fairly expensive: they are the second most expensive type of SHS in HCMC. Yet, they are also the most popular type of system, since they provide a near constant supply of power, which is the primary reason for the use of solar power in HCMC. Indeed, in HCMC, households which install grid-tied systems with battery backup often have specific needs like medical or professional, or they desire to have a 24/7 supply of power. Many households using grid-tied systems with battery backup also install smart systems to control their houses' security features and appliances, oftentimes remotely via smart devices (Le, 2015).

According to the majority of our informants, households that install grid-tied systems with batteries are typically solar power enthusiasts and well-to-do families. The former often install these systems on their own, which significantly reduces their costs. The latter are mostly located in new urban areas (such as Districts 2 and 7), where a sizeable population of *nouveau riche* and upper middle class Vietnamese families, overseas Vietnamese and expatriates live.

Consensus among the various installers in HCMC denotes that many of these solar enthusiasts and households express the need to differentiate themselves from their neighbours, i.e. to have power when the neighbourhood is without. They are also more likely to be aware on benefits of solar power.

While we do not have the exact statistics, our informants indicate that District 1, 3 and 5 of HCMC do not have as many installed SHS as Districts 2 and 7. Districts 1, 3 and 5 are centrally located and home to a good number of office buildings and government departments, which in turn ensures a more stable supply of electricity from the power grid. As a result, households located in these districts are more inclined to rely on the cheaply priced grid power and are less keen to adopt solar power. This stands in contrast to the rural districts and outer most areas of HCMC which experience power outages and rolling blackouts frequently.

<u>Off-grid Systems</u>

Off-grid (or independent) SHS are disconnected from the power grid; batteries are therefore essential to balance periods of excess production and excess demand. To protect against shortfalls of power when systems under-produce and the batteries are discharged, diesel or gasoline generators can be added. Off-grid systems are typically found in remote areas where the power lines do not reach, or when it is prohibitively costly to extend power lines to the desired locations.

These systems have the advantage of lowest initial cost, when used only to run basic appliances such as a few light bulbs and fans as most often the case in rural areas in HCMC and are often sold in kit form. A typical configuration for a solar kit is shown in Figure 9. However, when used to power electric stoves or air conditioners, an off-grid can be the second highest systems in terms of initial cost.

Figure 9: Off-Grid Solar Kit (65Wph capacity)

Source: http://en.solarpower.vn/vi/spds/id246/Solar-Lantern-Solar-Kits/

Households with off-grid systems usually choose to use direct current (DC) appliances to save on the conversion losses that come with using an inverter to convert DC power to alternating current (AC). Most importantly, to install off-grid systems, designers/installers need to know exactly how much power the household requires and how much access it has to GHI (i.e, sunlight).

In HCMC, off-grid systems are the most commonly found type of SHS after grid-tied systems with battery backup.[10] Households in remote or rural areas which the power grid has not reached or where frequent power outages occur often choose to install off-grid systems. These systems generally consist of a solar array, a charge controller, and a small battery bank. They invariably include at least one light and a socket to power basic electrical appliances such as radios, mobile phone chargers, or televisions. They often come in the form of stand-alone systems with only one or two panels; a good example would be pre-made solar kits.[11] Often, these systems are not designed to run continuously, but for set amounts of time given the calculated power needs.

On the other side of the spectrum, there are convenient DC systems with batteries intended for small electronics that need to run day or night. These systems require low voltage and are usually employed in highway sign lights, gate openers, and communication boxes. These DC systems may be installed in areas where the power grid has reached, yet there exists the need for the electronics to run constantly.

Another common type of off-grid systems in Vietnam are solar direct systems. As the name implies, solar direct systems are used only when the sun shines and are without storage batteries. Hence, when there is no sun there is also no power. These systems are most often used for water pumping applications and venting fans for agricultural production in farms in remote or mountainous areas. There are no solar direct systems in HCMC.

[10] Solar water heaters are the most dominant application of solar energy in Vietnam and HCMC. Solar water heaters represent a special case of off-grid systems. Due to the high demand for hot water and a government-sponsored subsidy program which provides a million VND for each installed solar water heater, their presence has skyrocketed these past years (Huynh, 2015). A typical system includes a large solar panel and a water tank. The panel consists of glass tubes made of stainless steel aluminium nitride which works to absorb solar heat. The gathered heat is then used to warm up the water in the tank.

[11] Solar kits are the invention of a Vietnamese solar system manufacturer. Designed in compact trolleys that can be stored and moved about with ease, these kits offer enough power to run basic appliances such as several light bulbs, fans, phone chargers, and televisions. There are different kits with varying power capacities, which in turn determines their prices. Installation costs for solar kits are minimal.

Hybrid Solar-Generator Systems

For off-grid and backup power applications, some households may opt for hybrid systems. Hybrid systems combine off-grid or grid-tied systems with a tertiary power source such as wind turbines or gas/diesel generators, in addition to sun and the grid power.
The clear advantage of these systems is that they will provide power if the grid goes down and can still sell power back to a grid if desired (and allowed by the utility company). They are therefore “fool-proof” systems that provide around the clock power.

The biggest disadvantage of these systems is their complexity and cost. They require a high level of expertise to design and install, considering the various power sources and backup available. The battery bank also needs regular maintenance and must be replaced long before the solar panels need replacing. These systems are therefore expensive. Yet, some households or users still consider these costs a superior alternative to the cost and difficulty of bringing in grid power to remote locations. These systems are indeed best utilized in areas where the power grid power goes down very often or where connection to the grid is prohibitively costly or demanding.

In HCMC, hybrid systems are the least common type of SHS. In Vietnam, they can be found on islands disconnected from the power grid such as the Spratlys. (Viet Nam News, 27 July 2014)

In summary, at the present time, the number of SHS that are in use in HCMC is growing but remains very limited. Based on the interviews with installers and distributors we estimate that less than 350 SHS are currently in use HCMC. In addition, there are larger solar systems operated by a few large firms (e.g., Intel, Big C), apartment buildings (e.g., Connic Apartments), hotels and supermarkets. There is also a large (local government financed) system serving around 400 households operated in Thanh An commune in Can Gio district) with unstable power supplies.

5. Problems and Constraints to the Adoption and Uptake of SHS in HCMC

To determine the various constraints to the uptake of SHS in HCMC, we conducted semi-structured interviews with government agencies, distributors, manufacturers, installers and users of SHS. A total of 13 of the 16 manufacturers, installers and distributors of SHS operating in HCMC were interviewed, together with 10 users, three government agencies (including EVN), and three technical experts.[12] The general consensus from these interviews is that all renewable energy sources, including solar power, face a number of constraints that have delayed their development and uptake in Vietnam.

All user groups identified policy constraints and the high cost of equipment and installation as the two biggest constraints. Technical and informational issues have also deterred some users from installing SHS, although these do not seem to be a particularly acute constraint. Table 4 provides a detailed summary of the constraints to the uptake of SHS in HCMC mentioned by our 29 interviewees.

Policy Constraints

In Vietnam, solar power receives little attention from policy makers when compared to other forms of renewable energy, such biomass power and wind power and small-scale hydroelectricity. This observation is evidenced not only in the Power Development Plan VII, but also from discussions with SHS manufacturers/installers and users. Our informants highlight the need to have the proper "*chinh sach*" (roughly translated as "policy") - a generic term covering all aspects of public policy, including the regulatory framework,

[12] Two companies declined to be interviewed, and one company could not be interviewed despite having previously consented to such an interview. The remaining 13 companies were interviewed, mostly in face-to-face interviews.

Users of SHS proved much more difficult to identify. Initially the research team asked installers and distributors to introduce us to customers for whom they had installed systems. However, the majority of companies were unwilling to do this, stating that the identities of their customers was commercially sensitive information. So the majority of our user interviews came from volunteers from a posting to an online forum for electronics and technology enthusiasts (www.TinhTe.com) which has an active page devoted to solar power. The users interviewed are therefore unlikely to represent an unbiased sample of SHS users in HCMC.

ministerial decrees and decisions, relevant laws, etc. in the socio-cultural context of Vietnam. The majority of our interviewees argued for the need for government interventions to encourage the uptake of solar power, ranking policy constraints as the number one factor.

Table 3: Summary of Constraints

Constraints	**Companies** (n=13)	**Users** (n=10)	**Government Agencies** (n=3)	**Experts** (n=3)
	Per group of interviewees			
Aesthetic reasons	8%	0%	0%	0%
Budget availability to finance FiT	0%	0%	33%	0%
Construction codes and shading	8%	0%	0%	0%
Limited choices of products	0%	10%	0%	0%
Few willing investors	8%	0%	0%	0%
High initial costs of SHS	77%	90%	100%	33%
Inappropriate grid infrastructure	8%	0%	0%	0%
Insufficient economic volumes of SHS	0%	0%	0%	33%
Lack of government support, including FiT	85%	70%	100%	100%
Lack of quality assurance	0%	10%	0%	0%
Lack of warranty and after-sales service (for imported components)	0%	10%	0%	0%
Limited industry technical capacity	23%	0%	33%	33%
Limited or misleading information	23%	70%	100%	0%
Low electricity prices	23%	0%	0%	100%
Mandatory construction codes for installing SHS	0%	0%	33%	33%
More cost-effective renewable energy (RE) options	31%	0%	0%	33%
No agreed standards	15%	0%	0%	0%
No return on independent systems	8%	0%	0%	0%
Reluctance to adopt new technologies	8%	0%	0%	0%
Technical difficulties	0%	50%	0%	0%

Source: semi-structured interviews conducted by research team

Specifically, policy constraints included the following:

i. *Absence of government-sponsored financial incentives* such as FiT or net-metering schemes for solar power, in contrast to wind power and biomass power. More than 70 per cent of SHS, 85 per cent of companies and all government agencies identified this absence as critical to the slow uptake of SHS in HCMC.[13] Companies in particular noted that the inability to sell excess electricity production back to the grid means that it takes longer for households to payback their initial investment costs. In March 2015, the ECC of HCMC, mandated by the HCMC's People's Committee, has started to put in place a pilot scheme for net metering.

ii. *Low electricity prices* consistently discourage homeowners from switching to or adopting alternative sources of energy. As noted in Section 2, despite recent increases in tariffs, the price of electricity in Vietnam is among the lowest in ASEAN. Residential electricity tariffs are effectively capped for political reasons and also depend heavily on substantial indirect subsidies to power production. Al experts and almost a quarter (23 per cent) of companies argued that low electricity prices have deterred investments in renewable energy at both the firm and household level.

iii. *Absence of an effective regulatory framework and supporting policies*. SHS users, manufacturers, installers and distributors expect the government to take the lead in laying the foundation and supporting structures to encourage production and consumption of solar power. Currently there are simply no solar power development targets implemented within the relevant strategies such as the Master Plan for Power Development. Moreover, the government has yet to introduce regulatory standards for SHS, which leads to significant variations in product quality and prices.

Financial Constraints

Government departments' representative, users and manufacturers/installers of SHS uniformly agreed that the policy constraint is compounded by the fact that the cost of most SHS, despite the falling prices of solar panels and batteries, are still beyond the reach of

[13] It is important to point out that SHS manufacturers, distributors and installers clearly distinguished between other forms of government support and FiT. On the other hand, government departments' representatives and users included FiT as part of general government support. The summary of constraints in Table 4 has one label of "Lack of government support, including FiT" to account for both types of support.

many. Some 90 per cent of users, 77 per cent of companies and all Government agencies and experts stated that this was one of the major constraints to the uptake of SHS in the City.

From the perspective of experts/users, SHS are not an economically viable option due to high cost of SHS and their low generation capacity when compared to other renewable generation sources such as wind power.

From the perspective of manufacturers and installers, financial constraints include their limited access to capital, lack of financial support from the government and financing options from banks. One manufacturer we interviewed argued that solar power companies in Vietnam have difficulty in raising capital. Potential investors are few and far between, as most deem the investment environment and supportive regulation framework unfavourable. Existing financing is also inadequate for manufacturers to reap economies of scale in production and for distributors to build and maintain the necessary distribution systems.

In fact, in Vietnam, investment in solar energy is only considered profitable for solar water heating. The demand for solar water heating systems is large: households and businesses have been willing to invest in solar water heaters, thanks to their low initial cost and potential savings on electricity bills. Consequently, solar water heating has been able to mobilize investment from the private sector. Solar water heating systems are now produced domestically and are regarded as a mature technology. It should, however, be noted that many of our informants – especially government agency representatives - credit the government-sponsored subsidy program, which pays VND 1 million (approximately US$ 45) for each solar water heater, as the galvanizing force behind this uptake.

Technical, Informational and Other Constraints

From the perspective of SHS manufacturers/installers, constraints include the absence of quality examination by relevant authorities to ensure adherence to well-defined standards and the circulation of limited or misleading information about available products. Together, these two shortfalls diminish user awareness and trust in the industry – an observation readily shared by government departments' representatives.

Manufacturers/installers further list technical difficulties in relation to building construction and the construction code in HCMC as constraints. Due to poor planning and space constraints, houses and buildings in the inner districts of HCMC are often constructed to maximize the available area, which in turn can obstruct sunlight and poses safety hazards. Additionally, there is as yet no section within the construction code to guide the installation of solar panels.

Users are most concerned with the absence of credible information to go by when making the decision to purchase a solar home system. Approximately, 70 per cent of users mentioned this as a constraint. Users were further troubled by the absence of after-sales and warranty services, especially with imported products. Users who import and install components directly without going to a distributor would need to repair and maintain those components themselves, given that international solar power companies have yet to open their offices in Vietnam.

Although mentioned by more than half of the users, technical difficulties are not regarded as a major constraint. Those who employ the service of an installer let the installer take care of technical issues as well, whereas those who install their systems themselves are often technically adept at repairing and maintaining.[14]

From the perspective of government departments' representatives, it is imperative that the Vietnamese solar industry develops a strong domestic supply chain to drive down costs. Currently, Vietnam has four companies assembling photovoltaic panels and one company assembling and customising SHS for user's needs. However, all the solar cells and many of the PV panel used by these companies are imported.

[14] It should be noted that users who mentioned technical difficulties as a possible constraints were disproportionately solar technology enthusiasts and technical experts. Users from *Tinh Te* usually purchase, install, and maintain systems on their own. Therefore, they are also more likely to encounter technical difficulties than those who employ the services of distributors and installers.

6. Payback Analysis for Solar Home Systems

Installers' estimates of the payback period for different systems vary widely (from 4 years to never!).[15] Many users assert that they install SHS to ensure electricity during power cuts or because of technological preferences rather than for economic/financial reasons.

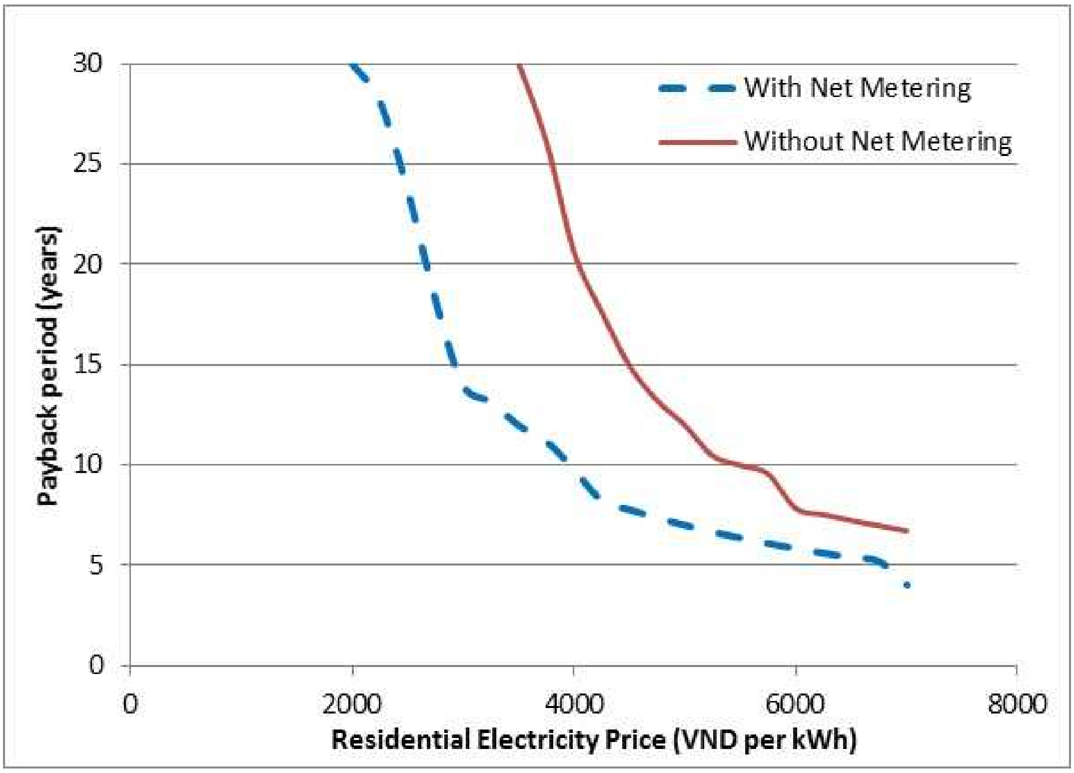
We have conducted a payback analysis of three types of representative Solar Home Systems using standard cash flow methods. The systems are: (i) a 1kWh grid-tied system with battery back-up; (ii) a 4kWh grid-tied system with battery back-up; and (iii) a 65Wh off-grid system in solar kit form. Note that we do not consider the case of a pure grid-tied system without battery back-up because a key motivation for installing a SHS in HCMC is to provide a back-up source of electricity during power cuts, which become more regular the further you go from the centre of the city and are also more common in the summer months.

One of the critical factors determining the payback period is whether households are compensated for any surplus electricity their SHS generate. Internationally, there are two main methods for doing this: net metering and feed-in-tariffs (FiT). With net metering, which requires only one meter, the household's electricity meter simply 'runs backwards' at times during the day when the SHS is producing more electricity than is being used by the household. The surplus electricity produced is valued at the same price as electricity purchased from the grid at other times, thereby reducing the household's net electricity bill. In contrast, a FiT requires two meters, the first to measure electricity consumption and the second to measure electricity generated. In order to encourage the production of renewable energy, the electricity which is generated and fed-into the grid typically receives a higher price than the electricity which the household purchases under FiT. Due to the simplicity of both installation and operation, net metering is used more often than FiT in other countries. Thus, although the use of FiT have been suggested in Vietnam, the payback analysis that follows assumes that net metering is used.

[15] The payback period is the length of time (usually measured in years) that it takes to recover the cost of an investment. It is determined by dividing the cost of the project by its annual cash inflows. All other things being equal, the better investment is the one with the shortest payback period. http://www.investopedia.com/terms/p/paybackperiod.asp

For a 1kWp grid-tied system with battery back-up costing VND 50 million , we estimate that the payback period exceeds 30 years if EVN's current average electricity price of VND 1,622/kWh is used and there is no net metering.[16] However, the residential tier 5 tariff of VND 2503/kWh is enough to produce a financial return to this system in 29.3 years. However, at a discount rate of 8 per cent, the net present value of this solar home system does not become positive until an electricity price of VND 4,365/kWh is reached. Finally, if the residential electricity price were to rise as high as VND 8,000/kWh, which is approximately the cost of generating electricity using a diesel stand-by generator, this system's payback period falls to just 5.2 years. The red line in Figure 10 shows how the payback period for this 1 kWh system varies without net metering.

Figure 10: Payback periods for 1 kWp Grid-Tied System with Battery Back-Up



Source: authors' calculations

It should be noted that the payback periods for this system are heavily dependent on the cost and the need to replace its backup batteries every eight years. At the current average residential electricity price, a pure grid-tied system of 1 kWp costing 40 million without backup batteries has a payback period of 20.6 years. This payback falls to 14.9 years at the

[16] Our payback calculations also assume a performance ratio of 80 per cent and that back up batteries costing VND 12.5 million need to be replaced every eight years.

Tier 4 residential price (VND 2242/kWh) and 10.3 years at VND 3,250 kWh. However, as noted above, we know of no pure grid-tied SHS installed in HCMC to date.

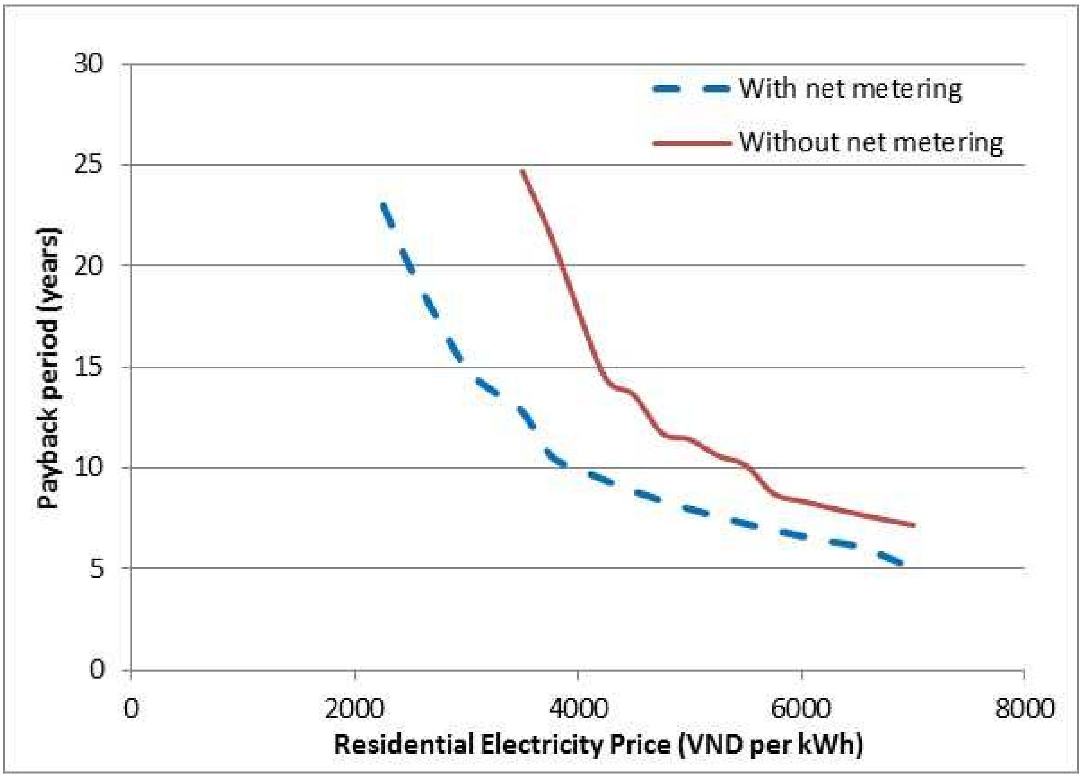
If net metering were to be introduced, the ratio of electricity generated which is used would rise while the need for battery storage would be reduced (although probably not eliminated, given user's desired for a back-up supply during power-cuts). To model this, we have changed the ratio of electricity generated to used from 80 per cent to 99 per cent, while assuming that the back-up batteries now only need to be changed every five years. With net metering and the average residential electricity price of VND 1622/kWh, the payback period for this system is now 23.9 years. However, if EVN's Tier 4 residential tariff of VND 2242/kWh is used, which is probably a more realistic price level for the well-off households who are likely to install SHS, the payback period system falls to just over 14.1 years. Looking to the future if an electricity tariff of VND 3,250/kWh were in force, the system's payback period falls to 9.8 years. The blue curve in Figure 10, shows the effect of introducing net metering on the payback periods for varying residential electricity prices.

Our second representative system is a 4 kWh grid-tied system with battery back-up costing VND 250 million. As shown in Figure 11, without net metering, the cost of this system cannot be paid back within 25 years until the residential electricity price reaches VND3,250 kWh. This is considerably more than highest residential pricing tier (VND 2,587/kWh) but is lower than the peak hour business tariff (VND 3,991/kWh) for a low voltage system. It is also the level that has been proposed for the national FiT. Even with an electricity price of more than VND3,250/kWh, the cumulative cash flow for this system turns back to negative in the years in which the back-up batteries (costing VND 50 million) need to be replaced. At a discount rate of 8 per cent, the Net Present Value of the system does not become positive until an electricity price of VND 5,225 kWh is reached.[17]
Again the introduction of net metering alters the financial viability of this system considerably.[18] The system can now be paid back in just under 20 years with a price of VND

[17] A pure 4 kWp grid-tied system with no battery back-up has a payback period of 15.4 years at the current Tier 4 residential electricity price and 10.6 years with a feed-in-tariff of 3,250.
[18] As the 1kWh system, we assume that: (i) the ratio of electricity generated to electricity used rises from 80 per cent to 90 per cent, and (ii) that the back-up batteries only need to be changed every five years, once a feed-in-tariff becomes available.

2,242 kWh, which is the current tier 4 residential electricity price. If the residential electricity price were to rise to VND 3,250, the system's payback period reduces to 11.7 years. With net metering, the net present value of the system at a discount rate of 8 per cent becomes positive once the electricity tariff reaches VND 3,165/kWh.

Figure 11: Payback Periods for 4 kWp Grid-Tied System with Battery Back-Up



Source: authors' calculations

It may therefore be concluded that even with net metering, unless either the price of the system were to fall substantially or government subsidies for installation were available, only a few households in HCMC would choose to install larger SHS. For the foreseeable future, this type of system are therefore likely to remain restricted to solar enthusiasts or to households who require access electricity 24/7.[19]

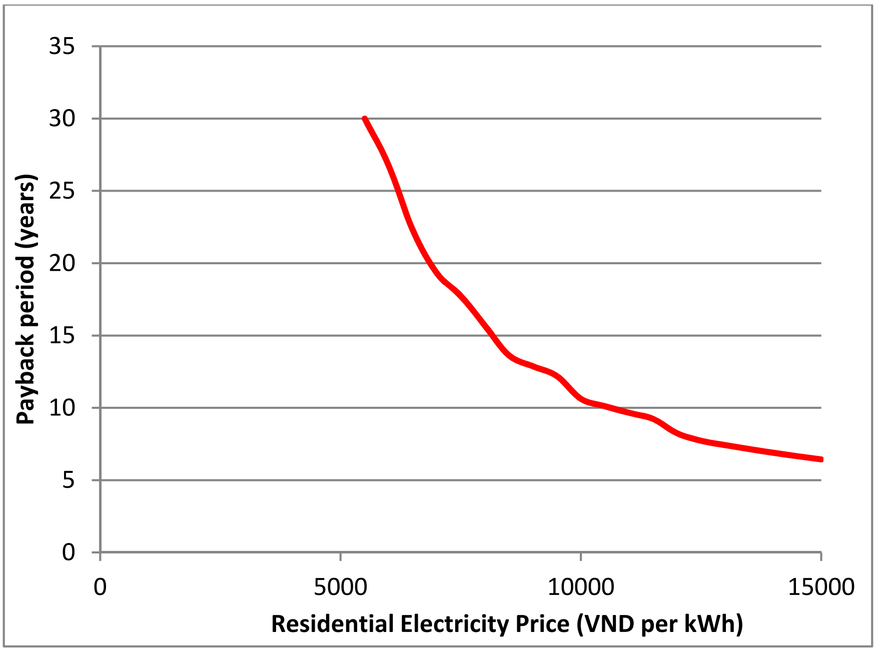
Thirdly, we consider the case of a small off-grid (independent) 65 Wp system designed to provide lighting in an area where there is either no mains electricity or very regular

[19] Such households would include those raising swallows and those with expensive tropical fish tanks.

interruptions to the mains electricity supply.[20] This system costs approximately VND 10 million to purchases in kit form and provides enough power to run two fluorescent light tubes or four light LED light bulbs for five to six hours. It is necessary to replace the batteries in this kit every 3 years.

Figure 12 shows the payback periods for this small off-grid system at different residential electricity prices. Assuming that batteries cost VND 1.25 million to replace, the payback period for this system is at least 25 years until the electricity price reaches VND 6,250/kWh. This price may seem very high until the cost of generating electricity using a small diesel or gasoline generator is considered. A small gasoline generator typically uses 0.55 litre/kWh, so it costs at least VND 10,000 to generate one kWh in fuel costs alone. With fuel costs of VND 12,000/kWh, the 65Wp solar kit's payback period falls to just 8.3 years.

Figure 12: Payback periods for a 65 Wp Off-Grid Solar System



Source: authors' calculations

Solar kits also offer added convenience over diesel generators, as they do not have to be started-up when the main power goes off.[21]

[20] Several of HCMC's outlying districts such as Can Gio, Nha Be, Tan Binh and Tan Phu have very intermittent mains electricity, with power cuts that can last as long as a day, especially in the dry summer season. ome outlying villages Tan Anh commune of Can Gio district, which do not have mains electricity supply at all.

[21] Some of the solar kits available, also now offer automatic smart switching when the main power goes off.

Summary and Policy Implications

With increasing urbanisation and rising incomes, the demand for electricity in Vietnam is growing by an estimated eight per cent per annum. The Government of Vietnam has adopted an ambitious Green Growth Strategy which seeks to reduce the carbon footprint of its industrial development, while increasing the share of renewable energy to 9.4 per cent by 2030.[22] We believe that with appropriate policy changes, solar energy has the potential to both contribute to the greening of Vietnam's electricity industry, and supplementing energy supply at peak periods of demand.

SHS typically consist of one or more photovoltaic (PV) panels, an inverter, control panel, metering, mounting and wiring which can generate electricity for residential users. Despite their additional costs, the majority of the limited number of SHS that are to date installed in HCMC also include backup batteries to supply electricity during power cuts and/or during the night. In more remote areas of Vietnam without access to grid electricity (including Can Gio district on the outskirts of HCMC), small off-grid SHS are becoming increasingly popular.

The research team has conducted around 30 semi-structured interviews with SHS distributors, installers and manufacturers, selected SHS users, plus government departments, public utility officials and technical experts based in and around HCMC. An in-depth review of electricity pricing and the policy environment was also undertaken. Cost-benefit analysis was then carried-out to estimate the likely payback period for three representative SHS: a medium-sized 1 kilowatt Watt peak (kWp) grid-tied system with battery backup, a larger 4 kWp grid-tied system with backup, and a smaller off-grid 65 Watt peak kit system. Given current electricity tariffs (and the absence of mechanism to feed surplus electricity generated back into the grid), the payback periods for both of the larger systems exceed 25 years. Such payback periods are too long to be attractive for even well-off households in HCMC's prosperous districts to install SHS, leaving only solar technology enthusiasts, households with a desire to be independent from EVN, and (perhaps) those with a passion for the environment/sustainability as the remaining users. Even with a

[22] To this should be added 11.8 per cent for large-scale hydro-power, which is well-established and not regarded as renewable energy in Vietnam.

doubling of residential electricity tariffs and the introduction of net metering, the payback period for these systems exceeds 13 to 14 years. In contrast, when the cost of diesel generators or other alternatives is considered, the payback period for the smaller off-grid kit system is at least 15 years. It is the convenience and low maintenance costs of such system, rather than the payback period, which explain the growing popularity of SHS in the more remote rural areas of Vietnam without (or with irregular access to) grid electricity.
The case for SHS in HCMC is not, however, completely lost. In the next three to five years, a number of changes to the domestic electricity market are expected that will make SHS systems more attractive as, at least, a supplemental source of residential electricity. These include the deregulation of EVN's position as monopoly supplier of electricity, the introduction of net metering or a FiT, and falling worldwide prices for both deep-cycle batteries and PV panels. In addition, although the levelised costs of solar electricity are not yet competitive with other renewables sources (in particular wind and small hydropower) in Vietnam, SHS have the potential to contribute additional generation capacity during peak load (and therefore more expensive) times and seasons. Unlike other newer 'renewable' sources (such as biogas and nuclear power), solar power is also a safe, well-established and well-understood technology for electricity generation.

We would therefore argue that SHS have a role to play in both diversifying Vietnam's evolving energy mix and in contributing to its Green Growth Strategy. Clearly, the raising of the residential tariff structure and the introduction of net-metering (or a feed-in-tariff) are the most important measures that would encourage the adoption and uptake of SHS in HCMC. Other measures, at either the provincial or national level, that would encourage the uptake of residential SHS in the medium-term include:

- Establishing a clear national policy for solar power and distributed energy generation
- Establishing agreed technical standards for SHS (by ENV and MOIT)
- Clarification of the requirements for SHS in the building code (by Department and Ministry of Construction)
- Removal of tariffs on electronic components used to produce SHS [23]

[23] While the importation of solar cells and solar panels are duty free, tariffs on other electronic components (e.g., control panels, inverters, meters) makes the production of SHS in Vietnam more expensive than in other countries.

- Time delimited installation subsidies for SHS, similar to the subsidies previously provided for solar hot water systems [24]
- Speeding-up the implementation of the agreed 'road map' for energy sector reform

To conclude, we believe that SHS in HCMC are a promising technology whose time has not yet come.

[24] See Mitsubushi Securities (2009).

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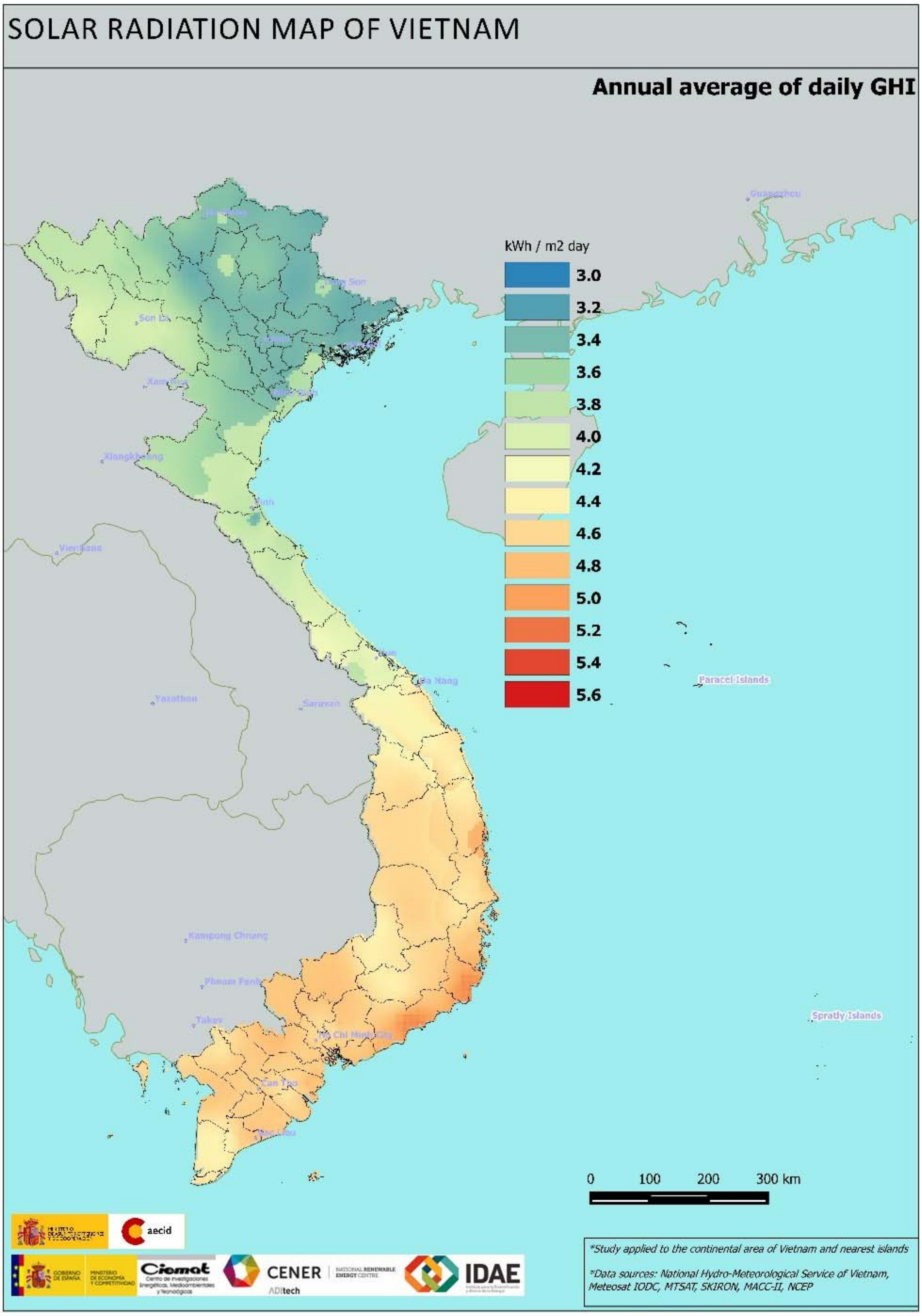
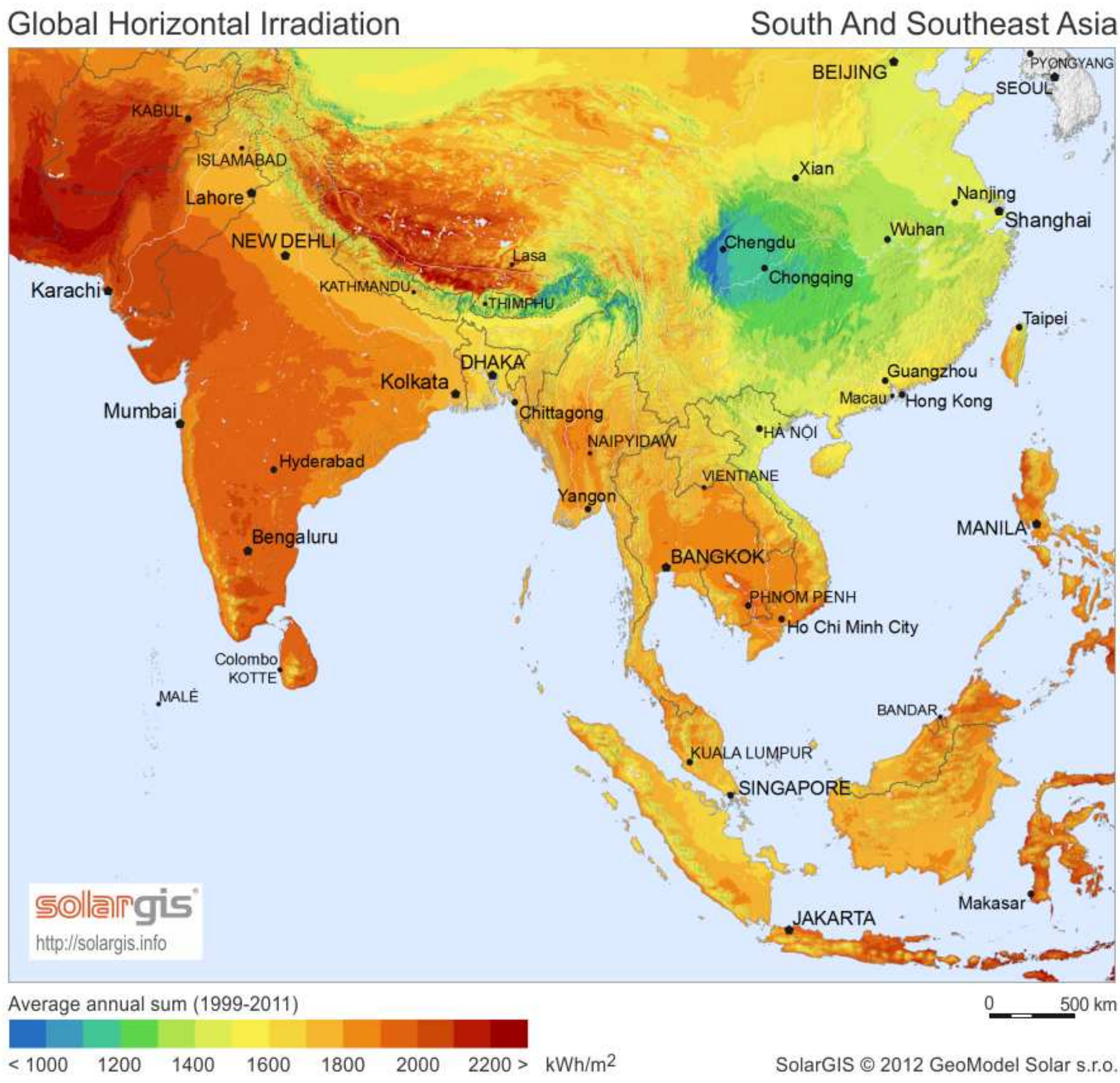
Appendix 1A



Source: AECID-EOIS-MOIT (2014)

Appendix 1B


Global Horizontal Irradiation
South And Southeast Asia
BEIJING
PYONGYANG
SEOUL
KABUL
ISLAMABAD
Lahore
Xian
Nanjing
Shanghai
Wuhan
Chengdu
Chongqing
NEW DEHLI
Lasa
KATHMANDU
THIMPHU
Karachi
Taipei
DHAKA
Kolkata
Guangzhou
Macau
Hong Kong
Mumbai
Chittagong
NAIPYIDAW
HÀ NỘI
Hyderabad
VIENTIANE
Yangon
MANILA
Bengaluru
BANGKOK
PHNOM PENH
Ho Chi Minh City
Colombo
KOTTE
MALÉ
BANDAR
KUALA LUMPUR
SINGAPORE
solargis
http://solargis.info
Makasar
JAKARTA
Average annual sum (1999-2011)
0
500 km
< 1000
1200
1400
1600
1800
2000
2200 >
kWh/m2
SolarGIS © 2012 GeoModel Solar s.r.o.

Appendix B: Constraint Rankings (1= Most Important)

Constraint	**Companies** (manufacturers, installers and distributors)												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Aesthetic reasons					5								
Construction codes and shading					3			4			2		
Few willing investors			4										
High initial costs of SHS		3	2	3	1	2		1	2	1	1	3	
Inappropriate grid infrastructure	4												
Lack of government support	3				2			2					3
Limited industry technical capacity				2									
Limited or misleading information		2		4			3	3					
Low electricity prices	1						2					1	

More cost-effective RE options				5								2	
No agreed standards		4									3		1
No feed-in tariffs	2	1	1	1		1	1		1	2			2
No return on independent systems			3										
Reluctance to adopt new technologies					4								

Constraint	Users									
	A	B	C	D	E	F	G	H	I	J
Few choices of products/installers	4									
High initial costs of SHS	2		1	1	2	2	1	2	1	1
Lack of government support, including FiT	3	1			1	1	3	1	2	
Lack of quality assurance		2								
Lack of warranty and after-sales service for imported components		3								
Limited or misleading information	1		2	2	3		2		3	2
Technical difficulties				3	4	3		3		3

Constraints	**Government Agencies**		
	A	B	C
Budget availability to support feed-in tariffs			3
Construction codes for installing SHS	5		
High initial costs of SHS	1	2	2
Lack of government support, including FiT	2	1	1
Limited industry technical capacity	3		
Limited or misleading information	4	3	4

Constraints	**Experts**		
	A	B	C
Construction codes for installing SHS	4		
High initial costs of SHS	1		
Insufficient economic volume of SHS			2
Lack of government support, including FiT	3	1	1
Limited industry technical capacity			3
Low electricity prices	2	2	1
More cost-effective RE options		3	

Appendix 3.a: Cash Flow Analysis for 1 kWp SHS without net metering

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Benefits																															
Capacity Power of System (kWp)	1																														
Hours of sunshine (pa)	2489																														
Performance ratio	0,8																														
Amount of Elec Generated (kWh pa)		1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2
Ratio of Elec Used to Elec Generated	0,6																														
Amount of Elec Used (kWh pa)		1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72	1194,72
Price of Electricity	3250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250
Cost of Electricity Used (VND millions)		3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284
Costs (VND millions)																															
Initial Capital Cost		50																													
Replacement Batteries	12,5								12,5								12,5								12,5						
Total Costs		50	0	0	0	0	0	0	12,5	0	0	0	0	0	0	0	12,5	0	0	0	0	0	0	0	12,5	0	0	0	0	0	0
Net Benefit		-46,1172	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	-8,61716	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	-8,61716	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284	-8,61716	3,88284	3,88284	3,88284	3,88284	3,88284	3,88284
Cumulative benefits		-46,1172	-42,2343	-38,3515	-34,4686	-30,5858	-26,703	-22,8201	-31,4373	-27,5544	-23,6716	-19,7888	-15,9059	-12,0231	-8,14024	-4,2574	-12,8746	-8,99172	-5,10888	-1,22604	2,6568	6,53964	10,42248	14,30532	5,68816	9,571	13,45384	17,33668	21,21952	25,10236	28,9852
(Fraction calculations)		nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	0,315759	0,684241	1,684241	2,684241	-1,6601	1,464948	2,464948	3,464948	4,464948	5,464948	6,464948
		19	0,315759																												
Payback Period (years)		19,31576																													
NPV @ discount rate =	0,08	-$14,96																													
IRR		4%																													

Notes:

(a) Electricity generated=capacity power x hours of sunshine x performance ratio. The performance ratio is also known as the coefficient for system losses and varies from 0.5 to 0.9.

(b) A ratio of electricity used to electricity generated of 0.6 is used to take account of periods during the daytime in which electricity generated is not used

(c) Assumes use of VRLA (Valve Regulated Lead-Acid) batteries that are replaced every 8 years

(d) Servicing costs are assumed to be minimal

Appendix 3.b: Cash Flow Analysis for 1 kWp SHS with net metering

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Benefits																															
Capacity Power of System (kWp)	1																														
Hours of sunshine (pa)	2489																														
Performance ratio	0,8																														
Amount of Elec Generated (kWh pa)		1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2	1991,2
Ratio of Elec Used to Elec Generated	0,99																														
Amount of Elec Used (kWh pa)		1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288	1971,288
Price of Electricity	3250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250
Cost of Electricity Used		6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686
Costs (millions)																															
Initial Capital Cost		50																													
Replacement Batteries	12,5								12,5								12,5								12,5						
Total Costs		50	0	0	0	0	0	0	12,5	0	0	0	0	0	0	0	12,5	0	0	0	0	0	0	0	12,5	0	0	0	0	0	0
Net Benefit		-43,5933	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	-6,09331	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	-6,09331	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686	-6,09331	6,406686	6,406686	6,406686	6,406686	6,406686	6,406686
Cumulative benefits		-43,5933	-37,1866	-30,7799	-24,3733	-17,9666	-11,5599	-5,1532	-11,2465	-4,83983	1,56686	7,973546	14,38023	20,78692	27,1936	33,60029	27,50698	33,91366	40,32035	46,72703	53,13372	59,54041	65,94709	72,35378	66,26046	72,66715	79,07384	85,48052	91,88721	98,29389	104,7006
(Fraction calculations)		nm	nm	nm	nm	nm	nm	nm	nm	nm	0,755434	0,244566	1,244566	2,244566	3,244566	4,244566	-5,51429	4,29348	5,29348	6,29348	7,29348	8,29348	9,29348	10,29348	-11,8743	10,34239	11,34239	12,34239	13,34239	14,34239	15,34239
		9	0,755434																												
Payback Period (years)		9,755434																													
NPV @ discount rate =	0,08	$13,46																													
IRR		12%																													

Notes:

(a) Electricity generated=capacity power x hours of sunshine x performance ratio. The performance ratio is also known as the coefficient for system losses and varies from 0.5 to 0.9.

(b) A ratio of electricity used to electricity generated of 0.99 is used to take account of occasional periods in which electricity generated cannot be fed-back into the grid

(c) Assumes use of VRLA (Valve Regulated Lead-Acid) batteries that are replaced every 8 years

(d) Servicing costs are assumed to be minimal

Appendix 3.c: Cash Flow Analysis for 4 kWp SHS without net metering

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Benefits																															
Capacity Power of System (kWp)	4																														
Hours of sunshine (pa)	2489																														
Performance ratio	0,8																														
Amount of Elec Generated (kWh pa)		7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8
Ratio of Elec Used to Elec Generated	0,6																														
Amount of Elec Used (kWh pa)		4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88	4778,88
Price of Electricity	3350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350	3 350
Cost of Electricity Used		16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925
Costs (millions)																															
Initial Capital Cost		250																													
Replacement Batteries	50								50								50								50						
Total Costs		250	0	0	0	0	0	0	50	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	50	0	0	0	0	0	0
Net Benefit		-233,991	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	-33,9908	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	-33,9908	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925	-33,9908	16,00925	16,00925	16,00925	16,00925	16,00925	16,00925
Cumulative benefits		-233,991	-217,982	-201,972	-185,963	-169,954	-153,945	-137,935	-171,926	-155,917	-139,908	-123,898	-107,889	-91,8798	-75,8705	-59,8613	-93,852	-77,8428	-61,8335	-45,8243	-29,815	-13,8058	2,203456	18,2127	-15,778	0,2312	16,24045	32,2497	48,25894	64,26819	80,27744
(Fraction calculations)			nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	0,862364	0,137636	nm	0,985558	0,014442	1,014442	2,014442	3,014442	4,014442
		22	0,137636																												
Payback Period (years)		22,13764																													
NPV @ discount rate =	0,08	-$100,75																													
IRR		2%																													

Notes:

(a) Electricity generated=capacity power x hours of sunshine x performance ratio. The performance ratio is also known as the coefficient for system losses and varies from 0.5 to 0.9.

(b) A ratio of electricity used to electricity generated of 0.6 is used to take account of periods during the daytime in which electricity generated is not used by the household

(c) Assumes use of VRLA (Valve Regulated Lead-Acid) batteries that are replaced every 8 years

(d) Servicing costs are assumed to be minimal

Appendix 3.d Cash Flow Analysis for 4 kWp SHS with net metering

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Benefits																
Capacity Power of System (kWp)	4															
Hours of sunshine (pa)	2489															
Performance ratio	0,8															
Amount of Elec Generated (kWh pa)		7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8
Ratio of Elec Used to Elec Generated	0,99															
Amount of Elec Used (kWh pa)		7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152
Price of Electricity	3250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250
Cost of Electricity Used		25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674
Costs (millions)																
Initial Capital Cost		250														
Replacement Batteries	50								50							
Total Costs		250	0	0	0	0	0	0	50	0	0	0	0	0	0	0
Net Benefit		-224,373	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	-24,3733	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674
Cumulative benefits		-224,373	-198,747	-173,12	-147,493	-121,866	-96,2395	-70,6128	-94,986	-69,3593	-43,7326	-18,1058	7,520928	33,14767	58,77442	84,40116
(Fraction calculations)			nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	0,70652	0,29348	1,29348	2,29348
		11	0,70652													
Payback Period (years)		11,70652														
NPV @ discount rate =	0,08	$7,53														
IRR		8%														

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Benefits															
Amount of Elec Generated (kWh pa)	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8	7964,8
Amount of Elec Used (kWh pa)	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152	7885,152
Price of Electricity	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250	3 250
Cost of Electricity Used	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674
Costs (millions)															
Replacement Batteries	50								50						
Total Costs	50	0	0	0	0	0	0	0	50	0	0	0	0	0	0
Net Benefit	-24,3733	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674	-24,3733	25,62674	25,62674	25,62674	25,62674	25,62674	25,62674
Cumulative benefits	60,0279	85,65465	111,2814	136,9081	162,5349	188,1616	213,7884	239,4151	215,0419	240,6686	266,2953	291,9221	317,5488	343,1756	368,8023
(Fraction calculations)	-3,46286	2,342393	3,342393	4,342393	5,342393	6,342393	7,342393	8,342393	-9,82286	8,391306	9,391306	10,39131	11,39131	12,39131	13,39131

Notes:

(a) Electricity generated=capacity power x hours of sunshine x performance ratio. The performance ratio is also known as the coefficient for system losses and varies from 0.5 to 0.9.

(b) A ratio of electricity used to electricity generated of 0.99 is used to take account of occasional periods in which electricity generated cannot be fed-back into the grid

(c) Assumes use of VRLA (Valve Regulated Lead-Acid) batteries that are replaced every 8 years

(d) Servicing costs are assumed to be minimal

Appendix 3.e Cash Flow Analysis for 65 Wp Off-Grid SHS

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Benefits																															
Capacity Power of System (kWp)	0,065																														
Hours of sunshine (pa)	2489																														
Performance ratio	0,8																														
Amount of Elec Generated (kWh pa)		129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428
Ratio of Elec Used to Elec Generated	1																														
Amount of Elec Used (kWh pa)		129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428	129,428
Price of Electricity	7500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500	7 500
Cost of Electricity Used		0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071	0,97071
Costs (millions)																															
Initial Capital Cost		10																													
Replacement Parts	1,25			1,25			1,25			1,25			1,25			1,25			1,25			1,25			1,25			1,25			1,25
Servicing ?																															
Total Costs		10	0	1,25	0	0	1,25	0	0	1,25	0	0	1,25	0	0	1,25	0	0	1,25	0	0	1,25	0	0	1,25	0	0	1,25	0	0	1,25
Net Benefit		-9,02929	0,97071	-0,27929	0,97071	0,97071	-0,27929	0,97071	0,97071	-0,27929	0,97071	0,97071	-0,27929	0,97071	0,97071	-0,27929	0,97071	0,97071	-0,27929	0,97071	0,97071	-0,27929	0,97071	0,97071	-0,27929	0,97071	0,97071	-0,27929	0,97071	0,97071	-0,27929
Cumulative benefits		-9,02929	-8,05858	-8,33787	-7,36716	-6,39645	-6,67574	-5,70503	-4,73432	-5,01361	-4,0429	-3,07219	-3,35148	-2,38077	-1,41006	-1,68935	-0,71864	0,25207	-0,02722	0,94349	1,9142	1,63491	2,60562	3,57633	3,29704	4,26775	5,23846	4,95917	5,92988	6,90059	6,6213
(Fraction calculations)			nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	0,740324	nm	0,028041	0,971959	-6,85381	1,684241	2,684241	-12,8051	3,396524	4,396524	-18,7563	5,108807	6,108807	-24,7076
		17	nm																												

Payback Period (years)		#VALUE!
NPV @ discount rate =	0,08	-2,67
IRR		4%

Key Variables for Sensivity Analysis

Ratio of Electricity Used to Generated

Residential Price of Electricity

Initial Cost of System

Replacement Batteries

Notes:

(a) Electricity generated=capacity power x hours of sunshine x performance ratio. The performance ratio is also known as the coefficient for system losses and varies from 0.5 to 0.9.

(b) 65Wp combo systems with